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GROWTH AND POVERTY IN RURAL CHINA: THE ROLE OF PUBLIC INVESTMENTS

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ABSTRACT

Public investment, together with institutional and policy reforms, has contributed substantially to rapid economic growth in rural China since the late 1970s. This rapid growth has also led to dramatic reductions in rural poverty. In this study we use a simultaneous equations model and time-series (1978-97), cross-sectional (25 provinces) data to analyze the differential impact of different types of public investments on growth and poverty reduction in rural China.

The results show that government expenditures on education have by far the largest impact on poverty reduction, and the second largest impact on production growth; it is a dominant “win-win” strategy. Government spending on agricultural research and extension has the largest impact on agricultural growth, and the third largest impact on poverty reduction. It is another win-win strategy. The next best investment is rural telecommunications, which gives the second largest impact on poverty reduction and the third largest impact on agricultural growth. The results also show that there are regional tradeoffs in achieving growth and poverty alleviation goals. If the government wishes to maximize its poverty reduction effects, then investments should be targeted to the western region. However, the sacrifice in growth by investing more in the western region is small. But, the government wishes to maximize the returns to growth in agricultural production, then it should definitely target the central region.

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1. INTRODUCTION

The number of poor in rural China declined from 260 million in 1978 to 50 million in 1997.[1] A reduction in poverty of this scale within such a short time period has never occurred before in the history of the world. The most rapid reduction occurred during the initial phase of the rural reforms from 1978 to 1984, when the number of rural poor fell from 260 million to 89 million. The incidence of poverty declined from 33 percent to 11 percent (MOA 1998). However, between 1984 and 1989 rural poverty began to rise again, and it was not until 1990 that absolute poverty resumed its decline. The rapid decline of rural poverty from 1978 to 1984 was highly correlated with income growth associated with increases in agricultural production, while the rise of poverty from 1985 to 1989 was associated with stagnant rural incomes. Despite relative

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[1] The number of rural poor each year was reported by various issues of *China Agricultural Development Report*, a white paper of the Ministry of Agriculture. The poverty line is defined as the level below which income and food production are not sufficient to meet subsistence levels of food intake, shelter and clothing. By this standard, there are virtually no urban poor. However, there are very large numbers of near poor—i.e., those people with levels of income and food production slightly

greater than subsistence needs—in rural and, increasingly, urban China (Piazza and Liang 1998).

stagnation in income growth since 1990, rural poverty has declined at a more rapid rate, indicating that factors other than growth have contributed to poverty reduction.

The literature on Chinese agricultural growth and rural poverty reduction is extensive.[2] But few have attempted to link growth and poverty reduction to public investment.[3] The purpose of this study is to investigate the causes of the decline in rural poverty in China, and particularly to quantify the specific role that government investments may have played. We seek to quantify the effectiveness of different types of government expenditures in contributing to poverty alleviation. Such information can assist policy makers in targeting their investments more effectively to reduce poverty in the future. More efficient targeting has become increasingly important in

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[2] The rapid growth in Chinese agriculture after the reforms has triggered numerous studies to analyze the causes or sources of the rapid growth. These studies include McMillian et al. (1989), Fan (1990), Fan (1991), Lin (1992), Zhang and Carter (1997), and Fan and Pardey (1997). Most of these studies attempted to analyze the impact of institutional changes and the increased use of inputs on production growth during the reform period from the end of the 1970s to the beginning of the 1990s. Fan and Pardey (1997) were the first to point out that omitted variables such as R&D investment would bias the estimate of the sources of production growth. They found that, by ignoring the R&D variable in the production function estimation, the effects of institutional change would be overestimated to a large extent. In addition to R&D investment, government investments in roads, electrification, education, and other public investment in rural areas have also contributed to the rapid growth in agricultural production. Omitting these variables will bias the estimates of the production function for Chinese agriculture as well.

[3] In spite of the extraordinary success in the poverty reduction in rural China, there have been few studies on the causes of this success. These studies include World Bank, 1992; Jalan and Ravallion, 1996; Jalan and Ravallion, 1997; Chen and Ravallion, 1996; Gustafsson and Li, 1998; Khan, 1997; and Rozelle et al, 1998. However, most of these studies have focused on the measures of rural poverty and its changes. The determinants of poverty reductions, however, have in large been ignored.

an era of macroeconomic reforms in which the government faces a more stringent budget constraint.

This study uses provincial level data for 1970-97 to estimate an econometric model that permits calculation of the number of poor people raised above the poverty line for each additional Yuan spent on different expenditure items. The model also enables us to identify the channels and the impacts of different types of government expenditures on poverty alleviation. For instance, increased government investment in roads and education may reduce rural poverty not only through improved agricultural production, but also through improved employment opportunities in the nonfarm sector. Understanding these different effects of different types of public spending can provide useful policy insights for the government to improve the effectiveness of its poverty alleviation strategy.

The analysis also allows us to calculate growth and poverty reduction effects by region. These regional differences provide important information on how the government can target its limited resources by region in order to achieve more equitable regional development, a key objective debated in both academic and policy making circles in China.

The paper is organized as follows. The next section reviews changes in poverty and public investment in rural China in recent decades. This is followed by sections describing our conceptual framework and model, and the empirical results. We summarize our findings in the concluding section.

2. POVERTY CHANGES AND PUBLIC INVESTMENTS

RURAL INCOME, INEQUALITY, AND POVERTY

Per capita income in rural China was extremely low prior to the rural reforms begun in 1978. In 1978, the average income per rural resident was only about 220 Yuan per year, or about $150 dollars (Figure 1).[4] During the 29 years from 1949 to 1978, per capita income increased by only 95 percent, or 2.3 percent per annum. China was one of the poorest countries in the world. The majority of rural people were struggling with day-to-day survival. In 1978, 260 million residents in rural China, or 33 percent of the total rural population, lived under the poverty line, and had inadequate food and income to maintain a healthy and productive life.

But this changed dramatically after the rural reforms began. Immediately after the reform, farmers' income soared. Per capita income increased to 640 Yuan in 1984, an annual growth rate over the period 1978-84 of 15 percent per annum. The income gains were shared widely enough to cut the number of rural poor, hence the rate of rural poverty, by more than half. By 1984, only 11 percent of the rural population lived below the poverty line. Meanwhile, income inequality, measured as the Gini coefficient, increased only slightly.

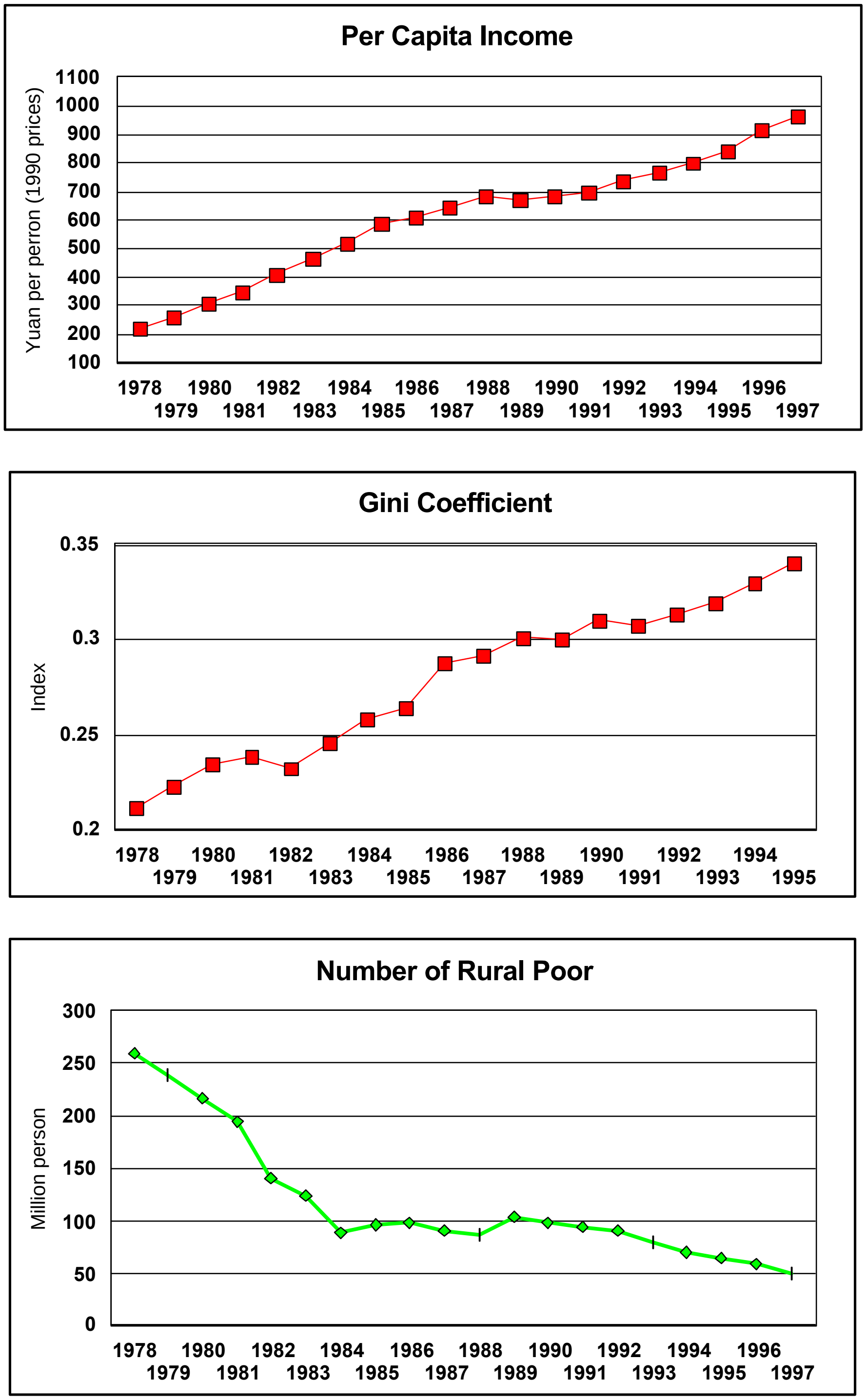
During the second phase of reforms in 1985-89, rural income continued to increase, but at a much slower pace of 3 percent per annum. This was mainly due to

[4]Total and per capita incomes are all measured in 1990 constant prices in this report.

the stagnation of agricultural production. As a result, there was no further reduction in rural poverty during this period, and the distribution of rural income also became less egalitarian (the Gini coefficient index rose from 0.26 to 0.30). The deterioration in the income distribution probably resulted from the changed nature of income gains. With crop prices stagnant and input prices rising, income gains had to come from increased efficiency in agricultural production and marketing or from nonfarm employment. Although the poor increased their access to modern inputs, their generally adverse production conditions constrained their gains. Moreover, increases in nonfarm income also contributed to a worsening income distribution, because the gains were mostly concentrated in the coastal areas where per capita income was already high and the incidence of poverty was much lower than elsewhere. The large areas in the west and border provinces, where the majority of the rural poor reside, lagged far behind. As a result, the number of poor increased from 89 million in 1984 to 103 million in 1989, a net increase of 14 million in 5 years.

It was not until 1990 that rural poverty began to decline again. The number of rural poor dropped from 103 million in 1989 to 50 million in 1997, a reduction of 9 percent per annum. The rate of rural poverty reduction was more rapid than income growth (five percent per annum during the same period), suggesting that the government’s anti-poverty programs were successful.

Figure 1 Income, inequality, and poverty change in Rural China



In terms of regional distribution, more than 60 percent of the rural poor in 1996 lived in border provinces such as Gansu, Yunan, Sichuan, Guizhou, Guangxi, Qinghai, Ningxia, Inner Mongol, and Xinjiang. Given the low population density in these areas, the poverty incidence is much higher than the national average. For example, 23 percent of the rural population in Gansu, and 27 percent in Xinjiang were under the poverty line in 1996. Another pocket of poverty concentration is in the Northern China Plain where the poor account for 22 percent of the national total. This area includes Henan, Hebei, Shannxi, and Shanxi where poor natural resources, particularly poor soil and lack of water resources, are the major reasons for the high concentration of rural poor.

TECHNOLOGY, INFRASTRUCTURE, AND PUBLIC INVESTMENT

Rapid development in technology and infrastructure has contributed not only to agricultural production growth, providing adequate food supply for an increasing and richer population, but also to the development of the rural nonfarm sector. The latter has become increasingly important for poverty reduction in rural areas.

R&D—China's agricultural research system expanded rapidly during the past four decades and is now one of the largest public systems in the world. It employs more than 60,000 senior scientists and, in 1997, spent 2.7 billion Yuan (1990 prices) on research conducted at national, provincial, and prefectural research institutes and agricultural universities.[5] In the early 1990s, the Chinese system accounted for over 40 percent of the less-developed world's agricultural researchers and 35 percent of its total research expenditures.[6] However, the Chinese agricultural research system has experienced many ups and downs over recent decades. Right after the foundation of the country in 1949, China's investment in agricultural research was minimal, but it grew rapidly until 1960 (Figure 2). The growth in the 1960s was relatively small due to a three-year natural disaster (1959-61) and the Cultural Revolution (1966-76). Investment increased steadily during the 1970s, but this growth slowed down during the 1980s, and grew only by 23 percent during the entire ten-year period. In the 1990s, agricultural research expenditures began to rise again, largely due to government efforts at boosting grain production through science and technology.

Several studies have attempted to quantify the impacts and returns to research investment in agricultural production. Fan and Pardey (1997) attributed about 20 percent of agricultural output growth from 1965 to 1993 to increased public investment in agricultural R&D. The estimated rates of returns to R&D investment range from 36 percent to 90 percent (Fan, 2000). Although no study has quantified the effects of these investments on poverty reduction, there are good reasons to think that increased agricultural production from research investments has led to trickle down benefits for the rural poor.

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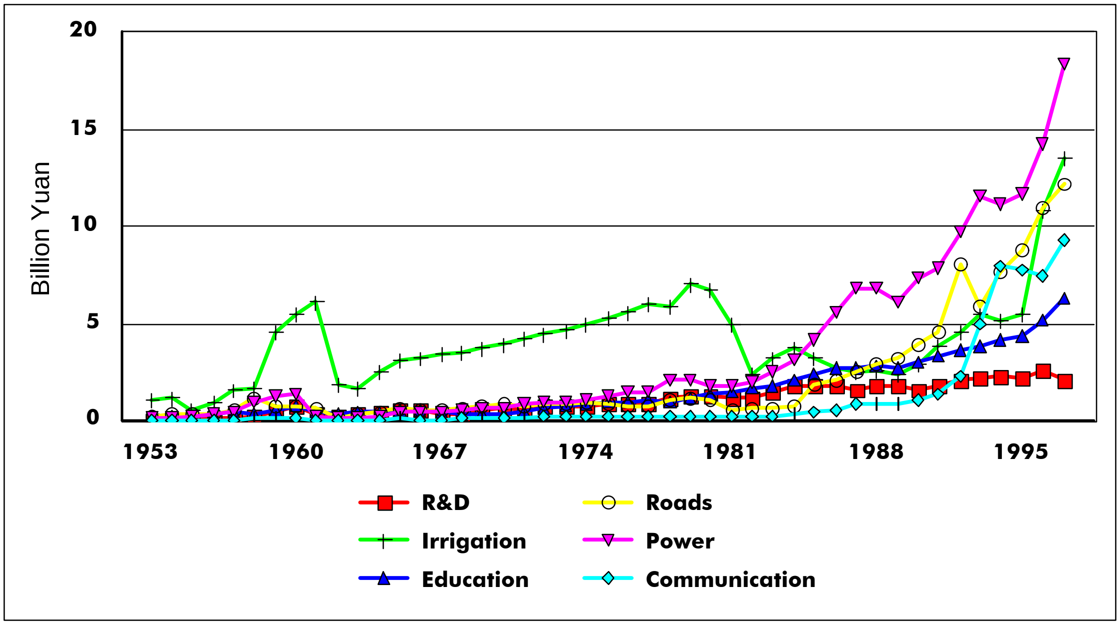
[5] In 1997, research expenditures in the Chinese agricultural research system (including research expenses by agricultural universities) were 2.7 billion in current Chinese Yuan. This is equivalent to $330 million measured by nominal exchange rate, and $1.4 billion measured by 1997 purchasing power parity (Fan, 2000).

Figure 2 Public investment in rural China



Irrigation—Due to concentrated rainfall during the monsoon, China's early civilizations developed agricultural systems that were dependent on water conservation and irrigation. The greatest expansion of irrigation facilities took place between 1949 and 1977, when the irrigated area increased from 16 million to 45 million hectares (Table 1). About 70 percent of grains as well as most of the cotton and other cash crops are produced on irrigated land. Many Chinese rivers are tapped for irrigation, with the Yangtze and the Yellow Rivers supplying much of the country's irrigation water through a system of dams and reservoirs that also function as flood control units. Annual usable supplies in the two river basins have doubled, and in some cases tripled since 1949, as the result of an ambitious program of dam

[6] Pardey, Roseboom, and Fan (1998)

construction. The northern and northwestern provinces of China make extensive use of groundwater resources. By 1997, 84,937 reservoirs, with a storage capacity of over 458 billion cubic meters, had been constructed.[7]

In terms of public investment, the government assigned top priority to irrigation immediately after 1949. In 1953, the government spent 1 billion Yuan on irrigation investment, 60 times larger than the amount spent on agricultural research (Figure 2). Investments in irrigation continued to increase until 1966. Under the commune system, it was rather easy for the government to mobilize large numbers of rural laborers to undertake large irrigation projects. As a result of this increased investment, more than 10 million hectares of land was brought under irrigation. However, there was little additional investment between 1976 and 1995. In fact, investment declined from 1976 to 1989. In 1989, irrigation investment was only 44 percent of that in 1976. During this period, there was no increase in the irrigated area in Chinese agricultural production. In response to the grain shortfall and large imports in 1995, the government sharply increased investment in irrigation in 1996 and 1997. But further expansion is difficult because of competing industrial and residential uses

[7] Information in this paragraph was summarized from the annual *Water and Power Yearbooks* (Water and Power Publishing House, Beijing).

of water, and declining land areas with irrigation potential. As a result, the returns to investment in irrigation may decline in the future.

Table 1 Development of irrigation, education, and infrastructure in China

Year	Irrigated area	Irrigated area as % of arable land	Primary school enrollment rate	Illiteracy rate of agricultural laborers	Road length	Rural electricity consumption	Rural telephones
		%	*%*		*Thousand kms*	*kw*	
1953		23.25	43		137	0.50	
1957	27		61.7	na		1.40	1850
	31	32.94		na	464		8470
1965		34.67	84.7		515	37.10	
1970	38		84.7	na		95.70	8780
	43	47.60		na	784		11,490
1980		46.12	93.9	a		320.80	13,450
	44	45.87		27.9	942		14,980
1990		48.04	97.8		1028	844.50	
1995	49		98.5	13.5		1,655.70	80,700
	51	53.34		10.1	1226		178,660
1953 80		2.57	2.93	a		27.05	13.70
-90	0.44		0.41	na		10.16	6.28
-97	1.17		0.16	-9.76	2.55		32.64
-97	1.93		1.91	na		20.72	14.75

China Statistical Yearbooks, China Fixed Asset Investment Yearbooks, China Electronic Power Yearbooks, China Water Materials.

Note: For more details about the data sources, see Appendix 1.

Education—The education level of the Chinese population was one of the lowest in the world four decades ago. In 1956, less than one-half of primary and secondary aged children attended school (Table 1). The periods of the Great Leap Forward (1958-61) and the subsequent Cultural Revolution (1966-76) were very disruptive times for Chinese society in general and its education in particular. The educational infrastructure was decimated as a result of the revolutionary struggles, and students suffered because of a vastly watered-down or non-existent curricula. Perhaps the only gain (again at the expense of quality) was the delivery of elementary education to an unprecedented percentage of school-aged children, largely because agricultural collectivization allowed for the creation of large numbers of "commune schools," overseen directly by the collectives rather than by higher-level agencies. The enrollment rate of school aged children rose from 43 percent to 97 percent by 1976. In 1983, more than 90 percent of all rural children were enrolled in school, only slightly lower than the urban rate of 98 percent. Since 1978, China has adopted an education policy of "nine-year compulsory schooling system", which requires all children to attend school for at least nine years to finish both primary and junior middle-school programs.

As a result of these efforts, the illiteracy rate of the adult population (15 years and older) dropped from 48 percent in 1970 to less than 10 percent in 1997. Consequently, labor quality has improved substantially, with a decline in the illiteracy rate of agricultural laborers from 28 percent in 1985 to 10 percent in 1997. This improved human capital in rural areas provided a great opportunity for farmers to use modern farming technology, and to engage in nonfarm activities in both rural township enterprises and urban industrial centers.

In terms of expenditure, the government has spent about 2 percent of total national GDP on education, which is much lower than many developed countries, but higher than many developing countries. However, the total expenditure on education is much higher, because rural education is also largely supported by rural communities, and their expenses on education are not counted in the formal government budget.

Despite extraordinary success in basic education in China, many poor have not been reached by the government's efforts. Official statistics show that among the poorer half of the townships in 35 counties supported under a World Bank project in Yunan, Guizhou, and Guangxi, the average enrollment rate was at least 10 percentage points lower than the national average for the same age group (Piazza and Liang, 1998). Special household surveys even documented greater disparities at the village level. The State Statistical Bureau's (SSB's) 1994 survey of 600 households in the poorest townships of these 35 counties showed that the average enrollment rate for children ages 6 to 12 was only 55 percent. It is not surprising that official statistics in these counties also indicate that the average literacy rate for the total population is only 35 percent (Piazza and Liang, 1998).

Infrastructure—Development of rural infrastructure is key to rural social and economic development. But for the past several decades, the government has not paid much attention to the construction of rural infrastructure (Figure 2). Not until recently, did the government realize the important role of rural infrastructure in omoting agricultural production, rural nonfarm employment, and the living standard of the rural population.

Among all transportation facilities, roads are the most crucial to rural development. However, the mountainous topography in many parts of China h hindered the development of roads. In 1953, the total length of roads in China was only about 137 thousand kilometers, and the road density was about 14 kilometers per

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More

to 1976 (Figure 2). Nevertheless, the length of roads has increased gradually (Table

high quality roads such as highways connecting major industrial centers in coastal

road length.

Despite great efforts by the government for the past decade, road density in na is still low by international standards. By 1997, the average road density had

of the density in India (Fan, Hazell, and Thorat 1999).

In contrast to road development,

China has been the rapid electrification of villages during the past several decades.

India's road de
1950.

The introduction of electricity often profoundly affects village life. Electric lighting expands the productive and social hours in the day. Radios and television provide accessible, affordable entertainment and education. Power machinery can raise productivity and improve working conditions. Most important, electrification brings with it expectations for progress and a better future.

For the past several decades, China has given higher priority to electrification than to road development in its investment portfolio (Figure 2). Investment in power has increased 90 fold since 1953. Electricity consumption in rural areas increased from almost zero to 198 billion kw in 1997 (Table 1). The most rapid growth occurred in the 1970s and 1980s. The percentage of villages with access to electricity was 97 percent in 1996, and more than 95 percent of households had an electricity connection that year. This percentage was much higher than that of India in the same year.

Prior to 1980, growth in government investment in telecommunication was very slow (Figure 2), increasing from 166 million Yuan in 1953 to only 738 million Yuan in 1980. However, there has been explosive development in recent years, and the number of rural telephone sets increased from 3.4 million in 1992 to 17.8 million in 1997. This is the result of both public and private investments in the sector: from 1989 to 1996, public investment alone increased more than 10-fold.

PRODUCTION AND PRODUCTIVITY GROWTH

Policy and institutional changes, along with increased government investments in agricultural research, irrigation, and infrastructure, have markedly influenced growth in production and productivity in Chinese agriculture. Table 2 presents

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period of 1952 79, production growth was slow at 2.1% per annum, slightly higher

ion growth rate during the same period. There was virtually no gain

due to inefficiencies in the production system and misallocation of resources among

ies.

Table 2 Agricultural production and productivity growth

Year	Production	Land productivity	Labor productivity	Total factor productivity
Annual growth rates (%)				
1952-77	2.10	1.87	0.12	-0.42
1978-84	6.63	7.37	5.07	4.72
1985-89	3.17	2.64	1.39	0.95
1990-95	6.89	6.64	7.50	5.85
1952-95	3.72	3.57	2.22	1.50

Sources: Fan (1997).

As a result of the poor performance of the agricultural sector for more than two decades, the central government decided to reform the rural sector in 1978. During the initial stage of the reforms, state procurement prices of agricultural products were raised and rural markets were reopened for farmers to trade their produce from their private plots. After two years of experiments, the government began in 1981 to decentralize agricultural production from the commune system to

[9] For more details about the methodology and data sources of production and productivity measures, refer to Fan (1997).

individual farm households. By 1984, more than 99 percent of the production units had adopted the household production responsibility system (MOA, 1998).

Not surprisingly, both technical efficiency (from the decentralization of the production system) and allocative efficiency (from price and marketing reforms) increased significantly during this first stage of reforms. Production increased by more than 6.6 percent and productivity by 5.1 percent per annum.

The second phase of reforms undertaken in 1985-89 was designed primarily to further liberalize the country's agricultural pricing and marketing systems. However, a high rate of inflation increased agricultural production costs, while the government cut the marginal (above-quota) procurement price for grain in 1985. The overall agricultural purchase price index stayed only slightly ahead of overall inflation in subsequent years, reflecting an end to the productivity gains of the previous seven years.[10] Annual production growth was only about three percent, half of the annual rate achieved during the first phase of the reforms. Total factor productivity grew less than one percent per year, less than a quarter of the rate during the previous period.

The 1990s marked a new development stage in Chinese agriculture. The government continued to implement the market and price reforms, by further reducing the number of commodities under the government’s procurement system. The number of commodities subject to government procurement programs declined from 38 in 1985 to only 9 in 1991. In 1993, the grain market was further liberalized and

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[10] The rising cost of production was reported by the Ministry of Agriculture (various years), *Production Cost Survey.*

the grain rationing system that had been in existence for 40 years was abolished. In 1993, more than 90 percent of all agricultural produce was sold at market determined prices, a graphic indication of the degree to which agriculture in China has been transformed from a command and control to a largely free-market sector. It is expected that farmers' allocative efficiency improved substantially during this period of reforms. As a result, agricultural production and productivity continued to rise rapidly with growth rates of 5.6 percent and 3.9 percent per annum respectively (although lower than those during the first phase of the reforms). In 1994, procurement prices for grains increased by 40 percent. They increased again by 42 percent in 1996. Chinese agriculture has now entered a new stage; one in which the sector is subsidized rather than taxed.[11]

NONFARM EMPLOYMENT AND WAGES

One of the most dramatic changes in rural China in recent years has been the rapid increase of rural nonfarm enterprises. Employment in the nonfarm sector as a percentage of total rural employment grew from 7 percent in 1978 to 29 percent in 1997 (Table 3). In 1997, rural enterprises accounted for more than a quarter of national GDP, up from nearly zero even as late as 1978. In 1997, the GDP produced by rural industry in China was larger than the GDP of the entire industrial sector of

[11] Fan and Cohen (1999) have argued that China is at a turning point in its development, and is moving from taxing to subsidizing agriculture.

India.[12] Without the development of the rural nonfarm sector, the annual GDP growth rate from 1978 to 1995 would have been 2.4 percentage periods lower per annum.

[12] Calculated by the authors using data from the *World Development Report*, 1999.

Table 3 Development of the rural nonfarm sector

Year	Employment	Employment in total rural employment	Rural nonfarm	Rural nonfarm GDP national GDP	nonfarm wage
	Thousand	*%*		*%*	*1990 Yuan*
	2,243	7		4.0	640
	1,956	6		4.3	763
	6,715	18		6.7	1,141
	8,673	21		10.4	1,322
	12,708	28	4,662		2,001
1997		29	6,007		2,286
Annual growth rate (%)					
-85	16.96		20.56		8.61
1985-	5.25		20.44	9.27	
1990 97				15.30	8.14
-97	9.92		24.05		6.93

The rapid development of the rural nonfarm s

rapid national GDP growth, but also raised the average per capita income of rural residents. In 1997, more than 36 percent of rural income was obtained from rural

The success of the rural nonfarm -reaching impacts on

rapid development of rural industry and services provided a demonstration of the potential gains from reform, and created competitive pre

reform as well. Without successful reforms in agriculture, which increased agricultural productivity and released resources to work elsewhere, and rapid

he urban

sector since 1984 would have been impossible.

3. EMPIRICAL ANALYSIS

CONCEPTUAL FRAMEWORK

There have been few studies on the determinants of rural poverty in China. One significant feature of previous studies is the use of a single equation approach to determine the correlation between rural poverty and explanatory variables. There are at least two disadvantages to this approach. First, many poverty determinants such as income, production or productivity growth, prices, wages and nonfarm employment are generated from the same economic process as rural poverty. In other words, these variables are also endogenous variables, and ignoring this characteristic leads to biased estimates of the poverty effects. Second, certain economic variables affect poverty through multiple channels. For example, improved rural infrastructure not only reduces rural poverty through improved growth in agricultural production, but also affects rural poverty through improved wages and nonfarm employment. It is very difficult to capture these different effects in a single equation approach.

Building on previous studies, and following similar work on India by Fan, Hazell, and Thorat (1999), this study uses a simultaneous equations model to estimate the various effects of government expenditures on production and poverty through different channels. The formal structure of the system is given in equations 1 to 10. The definition of variables is presented in Table 4.

Equation (1) models the determinants of change in rural poverty (*P*).[13] They include growth in agricultural production (*Y*), changes in nonagricultural employment (*NAGEMPLY*), changes in rural nonfarm wages (*WAGES*) and the terms of trade (*TT*), and one-year lag of growth in rural population (*POP*).[14] Agricultural growth is included as a variable in the poverty equation because agricultural income still accounts for a substantial share of the total income of rural households. Even in 1997, the percentage

$$\Delta P = f(DY, DWAGE, DNAGEMPLY, DTT, DPOP_{-1}) \tag{1}$$

$$\begin{aligned} Y = f(&LABOR, LAND, FERT, MACH, RDE, RDE_{-1}, RDE_{-l}, \\ &IR, SCHY, ROADS, RTR, ELECT, ANRAIN) \end{aligned} \tag{2}$$

$$WAGE = f(ROADS, RTR, SCHY, ELECT, Y_{-1}, POP, UGDP_{-1}) \tag{3}$$

$$NAGEMPLY = f(ROADS, RTR, SCHY, ELECT, Y_{-1}, UGDP_{-1}) \tag{4}$$

$$IR = f(IRE, IRE_{-1}, IRE_{-j}) \tag{5}$$

$$ROADS = f(ROADE, ROADE_{-1}, \;, ROADE_{-k}) \tag{6}$$

$$LITE = f(EDE, EDE_{-1}, \;, EDE_{-m}) \tag{7}$$

$$RTR = f(RTRE, RTRE_{-1}, RTRE_{-l}) \tag{8}$$

$$ELECT = f(PWRE, PWRE_{-1}, \;, PWRE_{-n}) \tag{9}$$

$$TT = f(Y, Yn) \tag{10}$$

was as high as 64 percent. In less developed areas, this percentage is even higher (often over 90 percent). Nonfarm employment income is the second most important

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[13] All variables without subscripts indicate observations in year t at the provincial level. For presentation purposes, we omit the subscript. The variables with subscript "-1,...-j" indicate observations in year *t-1*,...*t-j*. Symbol Δ indicates difference operator in logarithm form.

source of income after agricultural production for rural residents in China. We use the agricultural wage and the number of nonfarm workers as proxies for nonfarm income. Moreover, we can distinguish the different impacts of changes in wages and the number of workers in the nonfarm sector on rural poverty reduction. These different impacts may have important policy implications for further poverty reduction. The terms-of-trade variable measures the impact of changes in agricultural prices relative to nonagricultural prices on rural poverty. Although the government has largely distorted these prices, they have a large impact on rural poor. It is hypothesized that farmers in China may benefit from higher prices in both the short and long run. In the short run, the poor benefit from higher agricultural prices because they are usually net sellers of agricultural products. And, in the long run, increased agricultural prices may also induce government and farmers to invest more in agricultural production, shifting the supply curve rightward.[15] Population growth also affects rural poverty since higher population growth may increase rural poverty if there is insufficient growth in rural employment. This is particularly important for a country like China where resources are limited and the population base is large.

Equation (2) models the agricultural production function. Labor, land, fertilizer, machinery, and draft animals are included as conventional inputs. We also include the following variables in the equation to capture the direct impact of technology, infrastructure, and education on production growth in agriculture: current

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[14] One-year lag of growth is used to avoid endogeneity problems.

and lagged government spending in agricultural research and extension (*RDE, RDE*$_{-1}$,... *RD*$_{-i}$); the percentage of irrigated cropped area in total cropped area (*IR*); average years of schooling of the rural population (*SCHY*); road density (*ROADS*); number of rural telephone sets (RTR); and rural electricity consumption *(ELECT*). Annual rainfall is also added to the equation to control for the weather shocks in agricultural production.

Equation (3) is a wage determination function. Agricultural wages are determined by development in infrastructure, improved education, one-year lagged growth in agricultural output, and non-agricultural GDP.[16] The impact of improved infrastructure on wages is often ignored in specifying wage determination equations. Ignoring this effect is likely to lead to underestimation of the impact of government spending on poverty, since wage increases induced by improved rural infrastructure can be potentially large, benefiting workers in agricultural and nonagricultural activities. Growth in agricultural output is included to model the linkage between growth in the agricultural sector and rural wages. Growth in non-agricultural GDP is used to control the effects of the urban sector on wages growth.

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[15] This is a traditional induced innovation theory proposed by Hayami and Ruttan (1985).

[16] We could also include agricultural production growth in the equation. But given the inelastic supply of agricultural labor in Chinese agricultural production, the estimated coefficient should be very small. In addition, adding production growth as a variable in the equation may cause multicollinearity between the agricultural production growth variable and other variables in the equation.

function of rural infrastructure and education, one year lagged growth in agricultural output and

Table 4 Definition of exogenous and endogenous variables in the model

Exogenous variables	
	Rural population growth.
IRE:	d capital accounts.
RDE:	accounts.
	Government expenditure on rural roads, from revenue and capital
EDE:	Government expenditure on rural education, from revenue and capital
RTRE:	Government expenditure on rural telecommunication, from revenue and capital accounts.
PWRE:	accounts.
	Growth in non agricultural GDP
	Annual rainfall.
T:	me trend.
P:	Percentage of rural population falling below poverty line.
	Years of schooling of the rural population.
RTR:	
ROADS:	Road density in rural areas.
	Percentage of total cropped ar private irrigation).
	Supply of electricity.
WAGE:	
NAEMPLY:	Percentage of nonagricultural employment in total rural employment.
	Agricultural growth (Törnqvist Theil index).
Yn	
TT:	Terms of trade, measured as agricultural prices divided by a relevant nonagricultural GNP deflator.

non-agricultural GDP.[17] Improved roads help farmers to set up small nonfarm businesses and to market their products beyond their villages and towns. Improved roads and education also help farmers to find and commute to jobs in towns. As with the wage equation, one-year lagged growth in agricultural and nonagricultural output is used to capture the employment effects of growth in agricultural as well as non-agricultural sectors.

Equation (5) models the relationship between government investment and the percentage of the cropped area under irrigation. Included in the equations are variables that represent current and past government spending on irrigation ($IRE, IRE_{-1},\ldots, IRE_{-j}$).

Equations (6), (7), (8) and (9) model the relationships between road density and current and past government investment in rural roads ($ROADE, ROADE_{-1},\ldots,ROADE_{-k}$), between the rural literacy rate and current and past government investment in education ($EDU, EDU_{-1},\ldots EDU_{-m}$), between the number of rural telephone sets (RTR) and government investment in rural telecommunication ($RTRE$, $RTRE_{-1}$, …, $RTRE_{-l}$), and between the supply of electricity ($ELECT$) and government investment in power ($PWRE, PWRE_{-1}, \ldots, PWRE_{-n}$), respectively.

Equation (10) determines the terms of trade. Growth in agricultural production in the province and at the national level (Y_n) increase the supply of agricultural

[17] Again, one-year lagged growth in agricultural and non-agricultural growth is used to avoid potential endogeneity problems in the employment and wage equations.

products, and therefore reduce agricultural prices. Lower prices will help the poor if they are net buyers of agricultural products, but may hurt the poor if they are net supplies of agricultural products. The inclusion of national production growth in the terms of trade for each province controls for the effect of production growth in other provinces on food prices through the national market. Initially, we also included some demand-side variables in the equation, such as population and income growth, but they were not significant and were subsequently dropped from the equation.

DATA, MODEL ESTIMATION, AND RESULTS

Data—A panel data set including 25 provinces over the period of 1970-1997 was constructed from various governmental sources. There have been several estimates of rural poverty in China. The official statistics indicate that the number of poor had declined to about 50 million by 1997. The World Bank (Piazza and Liang 1998) has similar estimates to the Chinese official statistics. A third set of estimates, which use a much higher poverty line (Ravallion and Chen 1997), indicate that a far greater proportion of the total population is subject to poverty, with a poverty incidence of 60 percent in 1978 and 22 percent in 1995. Khan (1997), using household survey samples, obtained 35.1 percent for 1988 and 28.6 percent for 1995. Although these poverty rates are higher than the official rates, the reported changes over time are similar to the official statistics.

This study will use provincial level poverty data. Khan (1997) estimated provincial poverty indicators (both head count ratio and poverty gap index) for 1988 and 1995 using household survey data. We use both official and Khan estimates in our analysis, but the difference in the results is small because the two sets of poverty figures share similar trends. Our final results are estimated based on the official data because of the availability of poverty data by province for more years.

A detailed description of data sources, coverage, and regional classification is provided in Appendix 1.

Functional Form—We use the double-log functional forms for all equations in the system. More flexible functional forms such as translog or quadratic impose fewer restrictions on the estimated parameters, but many coefficients are not statistically significant due to multicollinearity problems. Regional dummies are added to each equation to capture the fixed effects of regional differences in agroclimatic factors. Year dummies are also added to capture the effects of policy and institutional reforms.

Investment Lags—Government investments in R&D, roads, education, power, health, and irrigation can have long lead times in affecting agricultural production, as well as long-term effects once they kick in. One of the thornier problems to resolve when including government investment variables in a production or productivity function concerns the choice of appropriate lag structure. Most past studies use stock variables that are usually weighted averages of current and past government expenditures on certain investments such as R&D. But what weights and how many years lag should be used in the aggregation are currently under hot debate. Since the shape and length of these investments are largely unknown, we use a free-form lag structure in our analysis, i.e., we include current and past government expenditures on

respective productivity, technology, infrastructure, and education equations. Then we

investment expenditure.

length. The adjusted R^2 rmation Criteria (AIC) are often used by many economists (Greene 1993). In this report, we simply use the adjusted R . Since an R estimated from a simultaneous equations system does not provide the correct information about the goodness of fit, we use t ^{2} estimated from single

^{2} reaches a

^{2} in that it rewards goodness

eedom. The lags determined by the adjusted R approach are 20, 14, 16, 17, 12, and 17 years for R&D, irrigation, education, telecommunication, power, and roads, respectively.

Another problem related to the estimation of the lag structure is that

indepen *RDE*, $_{-1}$ *RDE*$_{-}$, ... and $_{-i}$

function) are often highly correlated, making the estimated coefficients statistically insignificant. The most popular approach to resolving this problem is to use what are

lled polynomial distributed lags PDLs.

coefficients are all required to lie on a polynomial of some degree *d*

use PDLs *i+1*

parameters for the lag distribution. For more detailed information on this subject, refer to Davidson and MacKinnon (1993). Once the length of the lags are determined, we can proceed to estimate the simultaneous equation system with the PDLs for each investment.

Since our provincial poverty data are only available for seven years—1985-89, 1991, and 1996— a two-step procedure was used in estimating the full equations system. The first step involved estimating all the equations without the poverty equation using the provincial level data from 1970 to 1997. Then the values of *Y*, *WAGE* and *NAGRMPLY,* and *TT* at the provincial level were predicted using the estimated parameters. The second step involved estimation of the poverty equation using the predicted values of the independent variables at the provincial level using the available poverty data for 1985-89, 1991, and 1996.

Results—The results of the estimated equations system are presented in Table 5. Most of the coefficients are statistically significant at the 5 percent confidence level (one-tail test) or better. The estimated poverty equation (equation (1)) supports the findings of many previous studies. Growth in agricultural production, higher agricultural wages, and increased non-agricultural employment opportunities have all contributed significantly to reducing rural poverty. The terms-of-trade variable is also negatively correlated with rural poverty, implying that higher agricultural prices raise farmers' income and reduce rural poverty. This is different from India where higher agricultural prices are positively correlated with rural poverty (Fan, Hazell, and Thorat, 1999). This difference stems from the fact that even poor farmers in China are net suppliers of agricultural products, while most o

buyers. The positive and statistically insignificant coefficient for population growth in the regression indicates that population growth is not an important factor slowing the

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agricultural research and extension, improved rural infrastructure, irrigation, and education have contributed significantly to growth in agriculture. The coefficient

Table 5 Estimates of the simultaneous equation system

(1)	ΔP	=	−	1.27ΔY	−	0.707 ΔWAGE	−	0.915 ΔNAGEMPLY	−	2.236 ΔTT	+	0.292Δ POP$_{-1}$			R^2 = 0.589
				(-1.88)*		(-2.45)*		(-1.67)**		(-2.04)*		(0.42)			
(2)	Y	=		0.098 LABOR	+	0.023 LAND	+	0.367 FERT	+	0.046 MACH	+	0.107 IR			
				(1.30)		(0.50)		(6.44)*		(1.73)*		(3.15)*			
			+	0.304 RDE	+	0.295 ROAD	+	0.049 RTR	+	0.087 ELECT	+	0.115 SCHY			
				(3.97)*		(3.45)*		(5.41)*		(2.37)*		(0.91)			
			+	0.078 ANRAIN											
				(4.55)											R^2 = 0.994
(3)	WAGE	=		0.248 ROADS	+	0.096 ELECT	+	0.242 RTR	+	0.339 SCHY	+	0.401 Y$_{-1}$	−	0.258 POP	
				(0.57		(0.61)		(5.62)*		(2.09)*		(1.67)		(-1.36)	
			+	0.120 UGDP$_{-1}$											R^2= 0.542
				(0.89)											
(4)	NAGEMPLY	=		0.219 ROADS	+	0.053 RTR	+	0.114 SCHY	+	0.236 ELECT	+	0.122 Y$_{-1}$	+	0.583UGDP$_{-1}$	R^2= 0.990
				(0288)*		(2.56)*		(2.36)*		(3.79)*		(3.23)*		(7.62)*	
(5)	IR	=		0.138 IRE											R^2= 0.975
				(3.371)*											
(6)	ROADS	=		0.1734 ROADE											R^2= 0.999
				(1.743)*											
(7)	LITE	=		0.1952 EDE											R^2= 0.978
				(1.755)*											
(8)	RTR	=		2.74 RTRE											R^2= 0.982
				(2.14)*											
(9)	ELECT	=		0.723 PWRE											R^2= 0.988
				(5.93)*											
(10)	TT	=	-	0.008Y	-	0.043 Yn									R^2= 0.939
				(0.31)		(1.88)*									

Notes: Both region and year dummies are not reported. Asterisk indicates statistically significant at the 10% level. The coefficients of the technology, education, and infrastructure variables are the sum of those for the past government expenditures.

reported here for agricultural research and extension is the sum of the past 20 years coefficients from the PDLs distribution. The significance test is the joint *t* test of three parameters of the PDLs.

The estimates for equation (3) show that improved rural roads and education have contributed to increases in agricultural wages, and increases in rural nonfarm employment have also pushed wages up. The estimates for equation (4) show that nonagricultural employment is mainly determined by agricultural growth,[18] and government investments in roads, education, and electrification. The estimates for equations (5) confirm that government investments in irrigation have increased the percentage of the cropped area under irrigation. They also show that improved irrigation is highly correlated with rural electrification. The estimated results for equations (6), (7), (8) and (9) show that government investments in roads, education, telecommunications and power have all contributed to the development of roads, to increased literacy, to increased number of rural telephone sets, and to the increased use of electricity, respectively. Most of the coefficients in these equations are statistically significant. Finally, the estimated terms of trade equation (equation (10)) confirms that increases in agricultural production do exert a downward pressure on agricultural prices, worsening the terms of trade for agriculture.

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[18] Mellor (1976), Rosegrant and Hazell (2000), and others have argued that agricultural growth has powerful growth linkage effects on the rural nonfarm economy, and our result supports this theory.

MARGINAL EFFECTS OF GOVERNMENT EXPEND
AND POVERTY

types of government expenditures on agricultural production and rural poverty. The estimated elasticity coefficients measure the direct impact of eac

the dependent variable in each equation. But the full model captures indirect as well as direct impacts. To capture the full impact requires totally differentiating the full

interest. The marginal returns are calculated by multiplying the elasticities by the ratio of the poverty or

presented in Table 6. The annual return to agricultural production is measured in

shows the number of poor people who would be raised above the poverty line for each 10 thousand Yuan of additional government expenditure. These measure directly useful for comparing the relative benefits of an additional unit of expenditure on different items in different regions. As such, they provide crucial information for

better achieve production growth and to reduce rural poverty.

An important feature of the results in Table 5 is that all the production-

-win" strategies in that they increase

ile at the same time reducing rural poverty. There appears to be no tradeoffs between these two goals for any individual investment.

However, there are sizable differences in the production gains and poverty reductions among various expenditure items and across regions.

Table 6 Effects on poverty and growth of additional government expenditures, by type of investment and region

	Coastal region	Central region	Western region	China
Returns to agricultural production		*Yuan/ Yuan investment*		
R&D	7.33	8.53	9.23	7.97
Irrigation	1.40	0.98	0.93	1.15
Roads	3.69	6.90	6.71	4.91
Education	6.06	8.45	6.20	6.68
Electricity	3.67	4.89	3.33	3.90
Rural telephone	4.14	8.05	6.57	5.29
Returns to poverty reduction		*Number of poor reduced per 10,000 Yuan*		
R&D	0.97	2.42	14.03	3.36
Irrigation	0.15	0.23	1.14	0.39
Roads	0.70	2.80	14.60	2.96
Education	1.79	5.35	21.09	6.30
Electricity	0.92	2.64	9.62	2.92
Rural telephone	0.98	4.11	17.99	4.02

For the country as a whole, government expenditure on education has by far the largest impact on poverty alleviation. Every additional 10,000 Yuan of investment in education raises 6.3 people above the poverty line. In addition, education investments have the second largest impact on production growth; each additional Yuan investment in education leads to 6.68 Yuan of additional agricultural output. Therefore, investing more in education is the dominant “win-win” strategy. Public

R&D has the largest impact on agricultural production and the third largest impact on rural poverty. It is another "win-win" investment strategy.

Investment in rural telecommunications has the third and second largest impact on production growth and poverty reduction, respectively. Road investments rank fourth in their production and poverty alleviation impacts. Investment in electricity has the fifth largest impact on poverty reduction and production growth. These investments in infrastructure (telecommunication, roads, and electricity) contribute to poverty reduction through increased nonfarm employment, as well as through agricultural production growth. The former often accounts for more than 50 percent of the total poverty reduction effect. Investment in irrigation has the least impact on both production and poverty alleviation.

Regional variations in the returns to government spending are large. In terms of production growth in agriculture, R&D investment has the highest return in the western region, while irrigation investment has the highest return in the coastal region. For education and rural infrastructure (including roads, electricity, and communication), the central region gives the highest return. In the coastal region, a large amount of land has already been converted for non-agricultural use due to rapid industrialization and urbanization. Moreover, the incentives to intensify farming are lower there because of greater nonfarm employment opportunities. On the other hand, the land in the western region is more marginal with limited water and low soil quality. Therefore, the major growth potential for agricultural production lies in the central region where land is relatively less scarce and agricultural production is still the main source of income for farmers.

In terms of poverty effects, all types of investments have their biggest impact in the western region, followed by the central region and then the eastern region. This is because most of the poor in China are concentrated in the west. There are some poverty pockets in the central region, but virtually none in the coastal areas according to the poverty data reported by the Chinese government. Therefore, investing more in the western region should be a top priority for the government if it wishes to reduce the number of poor. There are clearly some tradeoffs between growth and poverty alleviation if one looks across regions. However, the sacrifice in growth by investing more in the western region is small. But, if the government wishes to maximize production growth, then investment should definitely be targeted to the central region. However, if the government wishes to maximize poverty reduction, then investment should be targeted to the western region.

4. CONCLUSIONS

Using provincial level data for 1970-97, this study has developed a simultaneous equations model to estimate the effects of different types of government expenditure on rural poverty and production growth in China. The results show that government spending on production enhancing investments, such as agricultural R&D and irrigation, rural education and infrastructure (including roads, electricity, and communication) have all contributed to agricultural production growth and to reductions in rural poverty. But different types of investments yield different poverty and production effects, and these impacts vary greatly across regions.

Government expenditure on education has the largest impact on poverty reduction and the second largest impact on production growth; it is the dominant "win-win" strategy. Government spending on agricultural research and extension has the largest effect on agricultural production growth, and the third largest impact on poverty reduction. Government spending on rural infrastructure (communication, roads, and electricity) has the second, fourth and fifth largest impacts on rural poverty reduction, respectively. These poverty reduction effects mainly come from improved nonfarm employment and increased rural wages. Irrigation investment has had only modest impact on growth in agricultural production and an even smaller impact on rural poverty reduction even after trickle-down benefits have been allowed for.

The results also show that if the government wishes to maximize poverty reduction, then greater investments should be targeted to the western region. However, the sacrifice in growth by investing more in the western region is small. But if the government wishes to maximize agricultural production, then it should definitely target more of its investments to the central region.

APPENDIX 1: DATA SOURCES AND EXPLANATIONS

Most of the provincial data on output and inputs are taken from Historical Statistical Materials for Provinces, Autonomous Regions and Municipalities (1949-1989), and various issues of China's Agricultural Yearbook, China's Statistical Yearbook, and China's Rural Statistical Yearbook.

*Output*Agricultural output is measured as the value of gross agricultural production expressed in 1990 prices.

Labor—Labor is measured in stock terms as the number of persons engaged in agricultural production at the end of each year.

Land—Land in agriculture is taken to be the sum of sown area and grassland. This measure was chosen for several reasons. First, it approximates a flow-type variable by capturing temporal and cross-sectional variation in multiple cropping patterns. Second, it is a more broadly based estimate of total land use in agriculture than alternative arable land measures (which are limited strictly to cropped areas). Moreover, it is constructed here in a way that makes some attempt to account for differences in the quality of cropped versus grazed areas (a weight of 0.0124 is used to convert a unit of grassland into its sown-area-equivalent where the weight represents the relative production values of grazed to cropped areas (*China's Statistical Yearbook 1985,* 1986)).

Machinery—Machinery input is measured as the aggregate stock of machinery horsepower and draft animals

Irrigation—Irrigation services used in agriculture are proxied by irrigated area.

Fertilizer—Fertilizer is an aggregate of both chemical and organic fertilizers, both measured in pure nutrient terms. The data for chemical fertilizers are taken from official statistics. But the data for organic fertilizer are calculated by the authors. The FAO (1977) estimated that one animal (horse unit) produces about 4 tons of manure per year and a person produces 0.25 tons per year. The elemental nutrient component (N, P and K) of manure is about 2.2 percent while the manure actually used is about 75 percent of total availability. Therefore, the quantity of organic fertilizer used per year was estimated as [(0.25 x Rural Population + 4 x Numbers of Livestock) x 0.022) x 0.75].

R&D expenditures—Public investment in agricultural R&D is reported in the total national science and technology budget. The data reported here were taken from Fan and Pardey (1992), Fan (2000) and various publications from the Government Science and Technology Commission and the Government Statistical Bureau. Research expenditures and personnel numbers include those from research institutions at the national, provincial, and prefectural levels, as well as agricultural universities (only their research components).

Irrigation expenditures—Provincial irrigation expenditures refers to total government fiscal expenditures on the construction of reservoirs, irrigation and drainage systems, flood and lodging prevention, soil and water conservation, water supply and hydropower projects, and in maintaining these systems. The data prior to 1979 were taken from *Thirty Years of Water Conservancy Statistical Materials*

(Ministry of Water Conservancy, 1980). The data after 1978 are available in *China Water Conservancy Yearbooks* (various issues).

Education expenditures—Provincial total education expenditures are reported in various issues of *China Education Yearbooks* (People's Education Press), and *China Education Expenditure Yearbooks* (China Statistical Press). Provincial expenditures on primary education are only available since the 1980s. The percentage of primary education expenditure in total education expenditure in the 1980s was used to backcast the primary education expenditures to 1970.

Road expenditures—Road expenditures were reported by *China Fixed Asset Investment Statistical Materials, 1950-85* (China Statistical Press), and various issues of *China Transportation Yearbooks*. However, there is no breakdown between rural and urban road expenditures. This may not cause serious problem, since rural roads account for 70 percent of total roads.

Power expenditures—Provincial power expenditures are available in *China Fixed Asset Investment Statistical Materials, 1950-85* (China Statistical Press), and various issues of *China Power Yearbooks* (China Power Publishing House). We use the unit cost of electricity per kw to calculate the power expenditures for rural areas.

Telecommunication expenditures—telecommunication expenditures by province are available in *China Fixed Asset Investment Statistical Materials, 1950-85* (China Statistical Press), and various issues of *China Transportation Yearbooks* (China Transportation Yearbook Publishing House). However, as with expenditures on roads and power, there is no breakdown between rural and urban expenditures.

We use the number of telephones in rural and urban areas to interpolate the cost for rural telecommunications.

*Rural education*The literacy rate of rural labor is used as a proxy for rural education. The data on literacy rate of rural labor were published in various issues of *China Rural Statistical Yearbooks*, and *China Population Statistical Yearbooks*.

*Roads*Roads are measured as road density, defined as the road length in kilometers per thousand square kilometers of geographic area. Road length is obtained from various issues of *China Transportation Yearbooks*, China *Statistical Yearbooks*, and *China Rural Statistical Yearbooks*.

Electricity—Total rural electricity consumption for both production and residential uses by province are available in various issues of *China Rural Statistical Yearbooks*, and *China Agricultural Yearbooks*. In more recent years, *China Rural Energy Yearbooks* (China Agricultural Press) have also published the separate use of electricity for residential and production purposes by province. We use this new available information to backcast use by province for earlier years.

Rural telephones—Number of rural telephones is used as proxy for the development of rural telecommunication. The number of rural telephone by province was published in various issues of *China Rural Statistical Yearbooks*, and *China Statistical Yearbooks*, and *China Transportation Yearbooks*.

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